AFFORESTATION OF AGRICULTURAL LANDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY: THE STATE OF OUR UNDERSTANDING

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Abstract: The Lower Mississippi Alluvial Valley (LMAV) was originally forested with approximately 8.5 million ha of bottomland hardwood forests. During the past 200 years, all but approximately 2.5 million ha of these forests have been cleared and converted primarily to agriculture. However, afforestation efforts have increased steadily during the past 20 years, as values of these ecosystems have been recognized. This paper provides an historical account of bottomland hardwood forest losses and presents a review of afforestation options, opportunities, and challenges in the LMAV.

Key words: bottomland hardwood forests, forest restoration, forested wetlands, reforestation

Restoration of bottomland hardwood forest ecosystems on agricultural lands in the Lower Mississippi Alluvial Valley (LMAV) generally requires some level of afforestation to reestablish forests that were previously cleared for agriculture. Afforestation efforts to date have been encouraging, with more than 75,000 ha planted. The objective of this chapter is to review the current state of our knowledge of bottomland hardwood afforestation in the LMAV by presenting (1) the historical context that led to the demise of significant portions of this resource, (2) available programs to reestablish bottomland hardwood forests, (3) commonly used afforestation techniques, (4) explanations for afforestation successes and failures, (5) considerations for monitoring to determine if objectives are achieved, and (6) challenges and opportunities that are present for successful afforestation as a keystone for restoration of these unique and valuable forest ecosystems.

HISTORICAL LOSS OF BOTTOMLAND HARDWOOD FORESTS

Original Extent

The LMAV once supported the largest expanse of forested wetlands in the United States. Rich alluvial soils received periodic sediment additions from the world's third largest river and supported highly productive ecosystems (Putnam et al. 1960). The commonly accepted estimate of the extent of bottomland hardwoods in the LMAV prior to European settlement is approximately 8.5 million ha (21 million ac). This estimate is based upon the extent of alluvial soils and the extent of the flood of 1882 (The Nature Conservancy 1992). This was the best-documented flood that occurred before the present levee system was completed. While probably an overestimate, it corresponds well with later estimates of forestland clearing based upon a LMAV of slightly more than a total of 10 million ha (25 million ac) (MacDonald et al. 1979).

Forests of the region were variable in species composition, productivity, and structure. As many as 70 commercial tree species grew in southern hardwood forests (Putnam et al. 1960). Two very broad community types were recognized by early writers: the baldcypress-tupelo gum (*Taxodium distichum-Nyssa aquatica*) swamps and the oak-sweetgum (*Quercus* spp.-*Liquidambar styraciflua*) forests of higher sites. The LMAV is actually a series of five recognizable basins formed by tributaries of the Mississippi River. In general, the lower end of each basin is subject to backwater flooding when the Mississippi River is in flood and thus, the forest communities are those best adapted to prolonged saturation. Within each basin, however, soils and drainage are variable and several site types can be recognized (Hodges 1997, Meadows and Stanturf 1997). Higher sites, formed as natural levees, have a recognizable forest type, the riverfront hardwoods (Putnam et al. 1960). These front lands offered early settlers the greatest opportunities to establish permanent agriculture.

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History of Land Use

The LMAV has undergone the most widespread loss of bottomland hardwood forests in the United States. As much as 96% of this loss has been caused by conversion to agriculture (MacDonald et al. 1979, Department of the Interior 1988). About one half of the original forests were cleared between the early 1800s and 1935. A later surge in forest clearing for agriculture took place in the 1960s and 1970s in response to a strong worldwide increase in soybean prices (Sternitzke 1976).

Timber harvesting was not much of a factor in the LMAV prior to 1900 (Demmon 1929). Timber cleared from the land before sugarcane was planted was usually burned. After 1830, local markets for lumber and firewood developed (Harrison 1961). The primary harvested commercial species was baldcypress (*Taxodium distichum*), valued for its durability and resistance to termites (Williams 1989). Until the influx of northern capital and machinery in the late 1800s, timber harvesting in baldcypress swamps was done by hand from small boats. Beginning in 1880, the pull-boat system and later logging railroads were used to extract the cypress. Between 1905 and 1913, annual production was about 1 billion board feet (Williams 1989). Overcutting caused production to fall after that, and by 1956 the last cypress sawmill was closed. Land was sold for as little as \$0.25/ac by the federal government and by the states. For example, a British syndicate in 1883 purchased 0.5 million ha (1.3 million ac) of timberland in the Yazoo Basin of Mississippi (Williams 1989). Most of the timber harvesting pressure, however, was on the pine uplands.

Clearing and conversion to agriculture was widespread because of the high natural fertility of the alluvial soils, although periodic flooding and the need for drainage presented formidable obstacles. The earliest attempt at flood control in the LMAV was at New Orleans in 1717 (Parkins 1938). Both St. Louis and New Orleans were settled about the same time, but it took hundreds of years for the rest of the LMAV to be settled. During the 18th Century, French settlement along both sides of the Mississippi was for commercial farming, following the plantation model imported from the West Indies. Clearing was arduous and done by hand by contracting primarily Irish and German immigrant labor gangs (Harrison 1961). Between 1700 and 1800, high points along the river, including Baton Rouge, Natchez, Vicksburg, and New Madrid were settled.

By the time the French settlements were secretly ceded to Spain in 1762, scattered settlements were established along the Red and Missouri rivers, but most of the population lived between New Orleans and present-day St. Francisville, Louisiana. The current agricultural economy of the LMAV was foreshadowed by the introduction of cotton in 1740 and sugar cane in 1751 (Parkins 1938). An early observer riding up the river from New Orleans in 1810 described continuous plantations for 60 km (40 mi) to the west in Lafourche Parish. From there north to Pointe Coupee Parish, fully two-thirds of the land was cleared. Complexion of the settlement was changed greatly by the influx of Acadian settlers from Nova Scotia in 1766-1768. These Cajuns established subsistence farming and hunting and a distinctive culture in the lower valley. The few settlements upriver were mostly trading posts. In 1810, Arkansas Post near the mouth of the Arkansas River was the only settlement in Arkansas. In 1811-1812, the most severe earthquake recorded in North America occurred along the New Madrid Fault in Missouri. Because population was sparse, little property damage was suffered, but the landscape was irreparably changed. Towns and villages along the Mississippi River in Missouri, Kentucky, and Arkansas were destroyed. The river was affected as far south as Vicksburg, where river islands disappeared. Thousands of hectares of bottomlands sank from faulting, forming swamps and permanent lakes, including Reelfoot Lake in Tennessee.

Other changes in land development within the LMAV followed the transfer of sovereignty over the Mississippi Basin to the fledgling United States through the Louisiana Purchase of 1803. Migration into the bottomlands increased considerably after a series of treaties were concluded with the Choctaw and Chickasaw tribes, which opened the east bank of the Mississippi River to settlement. In 1820, the Treaty of Doak's Stand opened up the Mississippi Delta (Cobb 1992). As cotton land elsewhere in the South became depleted of nutrients, planters moved into the bottomland between the Mississippi River and the Yazoo River in Mississippi. The first white settlers probably arrived between 1825 and 1827, but by the 1850s, the Yazoo Basin of Mississippi was the premier new planting area for cotton in the South (Cobb 1992).

By 1850, a continuous chain of plantations ringed the Mississippi and tributary rivers. Early settlers chose the natural levees because they were the highest ground locally and because they had the best soil for growing cotton. Inland, only upland areas such as Crowley's Ridge and Macon Ridge in

Arkansas were settled before the Civil War. In the Yazoo Basin, settlements were along the Mississippi and Yazoo rivers and Deer Creek, a tributary of the Mississippi. Land away from the natural levees remained forested. In 1860, only 10% of the Yazoo Basin was cleared (Cobb 1992). After the War with Mexico in 1848, there was another influx of settlers. But the advent of the Civil War caused a reversion of much cleared land back to forest because of a decline in cropping and increased flooding caused by a lack of levee maintenance(Demmon 1929). Severe floods in 1862 and 1865 washed away large sections of levees. In addition to these natural disasters, military operations during the war damaged levees. After the war, local levee districts were hard pressed financially and appeals were often made to the federal government for flood protection (Harrison 1961). It was not until 1917, however, that a Federal Flood Control Act was passed. The federal role in flood control was firmly established following the devastating flood of 1927 (Harrison 1961).

From the beginning to the middle of the 20th Century, the LMAV saw three waves of new immigration. The first began in 1907 when the railroads and development companies promoted the immigration of farmers from the Lake States and the Corn Belt, especially into the Yazoo Basin. Much land forfeited for taxes and levee district assessments was available from the states. Thus, little new clearing occurred because most efforts went into re-clearing land where trees had regrown since the Civil War. A second period of immigration occurred during the Great Depression in the 1930s when hill farmers settled on tax-forfeited lands. Beginning in the 1940s through 1960, new crops brought additional opportunities. Expanding farming was established to grow rice on newly cleared slackwater clays, especially in the Cache River Basin of Arkansas. Expanded markets in post-war Asia caused an expansion of the rice industry into the Yazoo Basin in Mississippi, but this was on heavy clay ("buckshot") soils that were already cleared (Harrison 1961). The last wave of immigrants was formerly from the drought stricken southwestern states, who were farmers searching for pasturelands. This group settled mostly in northeast Louisiana and southeast Arkansas. Land clearing from 1950 to 1955 was greatly aided by a dry period (Harrison 1961). Clearing of forests on heavy soils subject to backwater flooding was excessive during 1950-55 (Table 1). Fully 22% of the land remaining in forests at the beginning of World War II was cleared by 1960.

The most recent phase of clearing bottomland hardwood forests for agriculture began in the 1950s and extended through the 1970s, driven by the introduction of soybean farming in the bottomlands (Sternitzke 1976, Hinton 1977). Soybeans have a short growing season (90 days or less) and they are adapted to a wide range of soils. Thus, soybeans became a commercially profitable alternative to forests, even on low-lying lands prone to late-season backwater flooding because they can be planted after the wettest time of the year when flooding is most common. Soybean acreage in the LMAV increased fourteen-fold from 1937 to 1977 (MacDonald et al. 1979). Nevertheless, county-level

Table 1. Estimated land clearing in the Lower Mississippi Alluvial Valley between 1945 and 1959. (Adapted from Harrison 1961, p. 309).

Delta area	Total land area	Approximate forest area in 1948	Percent of land area in forest, 1948-1951	Cleared, 1945 to 1950	Cleared, 1950 to 1955	Cleared, 1955 to 1959	Percent of forest land area cleared, 1945 to 1959	Total area cleared, 1945 to 1959
	(ha)	(ha)	(%)	(ha)	(ha)	(ha)	(%)	(ha)
Missouri	1,147,000	235,000	20%	15,000	21,000	11,000	23%	53,000
Arkansas	3,800,000	1,415,000	37%	117,000	144,000	99,000	28%	392,000
Mississippi	2,212,000	826,000	37%	26,000	48,000	36,000	15%	126,000
Louisiana:								
North Delta	1,437,000	868,000	60%	69,000	96,000	70,000	31%	268,000
South Delta	3,833,000	1,064,000	28%	37,000	51,000	38,000	13%	142,000
Total Area	12,429,000	4,409,000	35%	264,000	360,000	253,000	22%	981,000

Table 2. Afforestation programs and areas planted in the Lower Mississippi Alluvial Valley through 1998.

Program	Area (ha)
Wetland Reserve Program (USDA NRCS)[1]	76,500 currently enrolled
Conservation Reserve Program (USDA FSA)[2]	21,673 currently enrolled
Partners for Wildlife (USFWS)[3]	1,000 annually enrolled (total not available)
Partners for Flight (administered by Ducks Unlimited)	2,600 annually enrolled (total not available)
Wildlife Habitat Incentives (USDA NRCS)[1]	400 annually enrolled (total not available)
Environmental Quality Incentives (USDA NRCS)[1]	400 annually enrolled (total not available)

[1] United States Department of Agriculture Natural Resources Conservation Service.
[2] United States Department of Agriculture Farm Service Agency.
[3] United States Department of the Interior Fish and Wildlife Service.

data indicated less forest clearing during 1967 to 1977 compared to the previous decade (MacDonald et al. 1979). With passage of the "Swampbuster" provisions in the 1985 Farm Bill, clearing of forested wetlands for agriculture declined to only 15% of the total forested wetland loss that occurred in the southeastern U.S. between 1982 and 1992 (Shepard et al. 1998).

Current Status

Although estimates are imprecise, the consensus is there remain about 2.5 million ha (5 million ac) of bottomland hardwood forests in the LMAV. Most (over 95%) occur in Louisiana, Mississippi, and Arkansas (The Nature Conservancy 1992). Some large blocks of bottomland hardwoods are in public ownership (National Wildlife Refuges and the Delta National Forest), but most bottomland forests are in private ownership (Shepard et al. 1998). The largest contiguous block of bottomland forests is in the Atchafalaya Basin of Louisiana, which accounts for 31% of the total cover of bottomland forests in the LMAV (The Nature Conservancy 1992). A considerable portion of the remaining forest occurs on batture land, lying in the unprotected area between the mainline levees of the Mississippi River.

Remaining bottomland hardwood forests in Arkansas occur primarily along the Arkansas, White, and Cache rivers. The lower 25 km (15 mi) of the Arkansas River are largely undeveloped and it is one of only a few rivers in the LMAV where natural meander processes still occur. The Hatchie River in western Tennessee, a tributary of the Mississippi River, is the only wholly unchannelized river in the LMAV. There are approximately 56,000 ha (138,000 ac) of bottomland forests in the Hatchie River watershed.

Louisiana contains 59% of the remaining forested wetlands in the LMAV, mostly in the Atchafalaya and Tensas river basins, with 0.6 million ha (1.5 million ac) and 157,000 ha (388,000 ac), respectively. Land in the Atchafalaya Basin is somewhat protected from development by easements purchased by the U.S. Army Corps of Engineers to protect this area as a floodway (The Nature Conservancy 1992).

The Yazoo Basin in Mississippi contains approximately 243,000 ha (600,000 ac) of bottomland hardwoods, but the majority of the basin is in agriculture. In the lower basin, there are approximately 57,000 ha (140,000 ac) of nearly contiguous bottomland hardwood forests in public ownership, comprised of the Delta National Forest [24,000 ha (60,000 ac)], Panther Swamp National Wildlife Refuge [11,000 ha (27,000 ac)], and Lake George Wildlife Management Area [3,200 ha (8,000 ac)] managed by the State of Mississippi. An 8,000-ha (20,000 ac) managed tree farm, mostly in cottonwoods (*Populus deltoides*), is in private ownership in Issaquena County, Mississippi.

PROGRAMS TO REESTABLISH BOTTOMLAND HARDWOOD FORESTS

Reestablishment of bottomland hardwood forests is done for several reasons, including (1) restoration of forested habitat, (2) creation of forested habitat specifically targeted to enhance biodiversity and target species, (3) creation of adequate tree stocking to maximize habitat benefits as well as to provide a variety of silvicultural options in the future, and (4) establishment of a hard mast component for wildlife species (Strader et al. 1994). These objectives must be achieved with minimum financial investment to be successful on a large, landscape scale.

Active afforestation programs in the LMAV are listed in Table 2. The USDA NRCS has enrolled the most area, with approximately 76,500 ha (179,000 ac) enrolled in the Wetland Reserve Program (WRP) through 1998. Total area planted for afforestation through 1998 within the Arkansas, Louisiana, Mississippi portion of the LMAV is approximately 71,000 ha (175,000 ac), made up primarily of U.S. Fish and Wildlife Service Refuges, WRP contracts, and state wildlife management areas (Schoenholtz et al. 2001).

AFFORESTATION TECHNIQUES

Typical afforestation of former farmlands in the LMAV includes machine- or hand planting of 1-0 bareroot nursery stock or acorns (Allen et al. 2001). Disking is often used to prepare sites for planting. If nursery stock is used, seedlings are usually planted on 3.5 x 3.5 m (12 x 12 ft) spacing, resulting in planting of approximately 746 trees/ha (302 trees/ac). Acorns are most often planted on 3.5 x 1 m (12 x 3 ft) spacing for a total of approximately 2,989 acorns/ha (1,210 acorns/ac). The goal of most programs is to have at least 309 trees/ha (125 trees/ac) surviving after three growing seasons. Table 3 summarizes the most common afforestation alternatives. The cost of disking for site preparation ranges from approximately $25-40/ha ($10-16/ac). Planting of seedlings ranges from approximately $80 to $618/ha ($32-250/ac), whereas direct seeding costs range from approximately $85 to $335/ha ($34-136/ac) (King and Keeland 1999). Systematic planting is most often practiced because of its relative simplicity and efficiency. However, planting in random or clumped patterns may more closely mimic natural rees lishment patterns.

Sources of Reproduction

The most common sources of reproduction in the LMAV include seed and one-year-old bare seedlings propagated in tree nurseries. Conta seedlings are another option that is becor more widely used, particularly on sites that difficult to afforest (King and Keeland 1999), cuttings are the predominant form used for plai cottonwood. Other practices such as "topsoi that is done widely in revegetation of strip mines other highly degraded sites (Allen et al. 2001) ar applied to any substantial degree in the LMAV. gardless of the source of reproduction, it is cr to obtain quality material and to ensure han that maintains quality. Survey respondents frequently cited seed or seedling quality as the f influencing afforestation success(King and Ke 1999). Seed and seedling quality will be disc below.

Excellent guidelines are available on see lection, handling and storage for most of the bottomland hardwood species (e.g., Schopmeyer Bonner and Vozzo 1987, Johnson and Krinard Bonner 1993, Allen et al. 2001). Keys to su include collection of seed that is viable, matu capable of reaching maturity after collection from genotypes suited for the planting site, stor seed at proper moisture and temperature cond and careful handling of seed at all stages fro lection through planting.

Oaks (*Quercus* spp.), which are by far the widely used species for direct seeding in the L are classified as recalcitrant (i.e., they cann allowed to dry out) and their acorns have described as "the most difficult of all tem

Table 3. Common alternatives for afforestation of agricultural lands in the Lower Mississippi Alluvial Valley.[1]

Tree species	*Source of reproduction*	*Planting technique*	*Season of planting*	*Spacing pattern*
Oaks (*Quercus* spp.)	Bareroot seedlings	Machine	Winter	Systemati
Light-seeded species	Containerized seedlings	Hand	Spring	Random
Mixtures of oaks and light-seeded species	Seed	Aerial application of seed	Summer	Clumped
			Fall	

[1] All possible combinations of species, sources of reproduction, planting techniques, seasons, and spacing listed in this table have been used in the Lower Mississippi Alluvial Valley to varying extents.

Kormanik et al. 1998). In addition to ensuring an adequate number of FOLRs, nursery practices such as fall fertilization may improve seedling root growth potential, but the benefit of these practices remains unknown for LMAV bottomland hardwood species.

While economics and logistics generally dictate the use of seed or bareroot seedlings, container stock is coming into wider use in the LMAV (King and Keeland 1999). Container seedlings typically have more FOLRs and secondary roots than bareroot stock (Burkett 1996), and are not subjected to the stresses of root pruning and lifting, so they may perform better than standard bareroot stock on adverse sites (Rathfon et al. 1995). They offer a number of other potential advantages, such as shorter lead times for producing plantable stock, more efficient use of scarce or genetically improved seed, opportunity to inoculate seedlings with mycorrhizae, and ability to plant well into the growing season (Gulden 1983, Burkett 1996). Results of at least two trials in the LMAV indicate that container stock may have better survival and growth than bareroot stock or planted seed on flood- and drought-prone sites or when planted in the summer (Humphrey 1994, Burkett 1996, Burkett and Williams 1998, Williams and Craft 1998). As technology for producing and handling container seedlings continues to improve, they may become much more widely used in the LMAV.

In a survey of bottomland hardwood afforestation in the LMAV, Schoenholtz et al. (2001) reported that choosing between direct seeding and planting of seedlings has varied over time and among states and agencies. Direct seeding of acorns was favored during the late 1980s, as machines capable of planting acorns became available. However, by the late 1990s, planting of seedlings was favored. Choices of planting options provide advantages and disadvantages (Table 4). Direct seeding is less expensive, but generally not as reliable for successful establishment of trees.

Planting Techniques

The basics of tree planting have been worked out for decades, but, in practice, poor planting techniques still tend to be a common factor limiting afforestation success. Simple, well-understood mistakes, such as failing to carry out appropriate site preparation, planting bareroot seedlings too shallow, exposing seedling roots to heat and desiccation prior to planting, excessive or incorrect root pruning, and even planting cuttings upside down continue to occur (Clewell and Lea 1990, Kennedy 1993). Problems such as these are most likely to occur with inexperienced or poorly supervised planters (Clewell and Lea 1990).

One approach that generally leads to better success is mechanical (vs. hand) planting. An advantage of mechanical planting is that a smaller number of personnel is required, allowing for more focused training and supervision. Also, mechanical planting techniques help ensure more uniform placement of planting stock in the soil. In the case of seedlings, mechanical planting helps ensure that seedlings are planted deeply enough and without "J-rooting." Differences between mechanical and hand-planting in first-year performance of hardwood seedlings have been demonstrated most convincingly for upland sites (Russell et al. 1998), but similar differences might be expected on bottomland sites subjected to drought stress.

Uniformity of planting depth may prove beneficial in direct seeding, as well. Although acorns can be sown from 2.5 to 15 cm (1-6 in) deep (Johnson and Krinard 1985*b*, Kennedy 1993), planting at more precisely targeted depths may result in greater germination or growth. For example, Wood (1998) reported generally higher germination rates, less pilfering of acorns by rodents, and higher first-year stocking of Nuttall (*Q. nuttallii*) and willow (*Q. phellos*) oaks at a planting depth of 7-10 cm (3-4 in) compared to 3-5 cm (1-2 in) for acorns planted in March or June (Table 5). Other research has shown that germination is reduced at very shallow depths (e.g., surface sowing) or at depths greater than about 11 cm (5 in) (Johnson and Krinard 1985*a*, Smiles and Dawson 1995). In general, an intermediate sowing depth of 5-9 cm (2-4 in) is recommended for the LMAV; sowing deeper than about 11-12 cm (4-5 in) should only be done if high rodent depredation or severe drought conditions are expected (Johnson and Krinard 1985*b*).

Season of Planting

Optimal season for planting seedlings or sowing seed varies by type of seedling stock or by type of seed used. Bareroot seedlings have the narrowest planting season, which is generally from December to March in the LMAV. Successful establishment is more likely if seedlings are fully dormant at the time of lifting from nursery beds through to the time of planting. If kept in cold storage, it may be possible to extend the planting season for bareroot seedlings into May (Kennedy 1993), which can be an advantage on sites with

Table 5. Effects of planting date and sowing depth on first-year germination, rodent pilfering, and stocking of Nuttall (*Quercus nuttallii*) and willow (*Q. phellos*) oaks on a previously farmed wetland in Sharkey County, Mississippi ([illegible] Wood 1998).

Planting date	Planting depth	Nuttall oak			Willow oak		
		Germination	Pilfering	Stocking	Germination	Pilfering	Stocking
	(cm)	(%)					
Dec.	3-5	66.8 (7.2)[1] a[2]	5.8 (1.5) c	40.5 (6.0) abc	51.7 (6.8) ab	2.9 (1.0) b	31.5 ([illegible]
	7-10	76.0 (6.0) a	0.7 (0.3) d	54.6 (4.3) a	54.4 (7.6) a	1.1 (0.4) b	30.4 ([illegible]
March	3-5	34.5 (4.1) b	16.3 (3.5) b	22.5 (3.8) cde	26.0 (4.7) bc	6.8(2.4)ab	13.8 ([illegible]
	7-10	65.5 (5.0) a	3.7 (0.9) cd	48.1 (5.2) ab	56.5 (5.5) a	2.4 (1.4) b	40.7 ([illegible]
June	3-5	9.5 (2.4) b	20.7 (2.6) ab	6.0 (1.7) e	8.3 (3.0) c	10.0 (2.2) a	3.7 ([illegible]
	7-10	20.2 (4.6) b	21.9 (2.5) a	12.8 (2.5) de	23.9 (4.3) c	2.7 (0.6) b	16.9 ([illegible]

[1] Values in parentheses are one standard error of the mean.
[2] Within each column, means with different letters are significantly different at $\alpha = 0.05$, according t o Duncan's Mult[illegible] Range Test.

prolonged flooding. This practice has not been widely tested, however, and there is evidence that seedling viability is reduced by cold storage even for seedlings planted by March (Williams and Craft 1998).

A major advantage of both direct-seeding and container stock is that the planting period can be extended. Planting can readily be done in the late spring and early summer, after floodwaters have receded. In the case of direct seeding, successful establishment begins to decline rapidly by June, as demonstrated by Wood (1998) (Table 5), and seeding is not recommended from July to October, when soil conditions may be hot and dry (Johnson and Krinard 1987). Late fall plantings also are feasible with direct seeding of acorns. We are not aware of any attempts to plant containerized stock in the fall within the LMAV, but feasibility of planting this stock type from December to June has been demonstrated (Burkett and Williams 1998, Williams and Craft 1998).

Species-Site Compatibility

Much is known about the suitability of LMAV bottomland hardwood species to particular sites and soil types (Putnam et al. 1960, Broadfoot 1976, Baker and Broadfoot 1979, Burns and Honkala 1990, Miwa et al. 1993, Zimmermann 2001). The problem of species selection cannot be considered trivial, however, because it requires good information on site factors such as soil type, and timing, frequency, duration, and depth of flooding (Clewell and Lea 1990), which are not always easy to obtain.

At least two types of problems related to species-site compatibility occur in the LMAV. The first is failure to properly match species and [illegible] because of ignorance of species-site compati[illegible] guidelines or to misguided desires to plant [illegible] species because of perceived economic or wil[illegible] values. The second type of problem encount[illegible] difficulty in obtaining reliable information on [illegible] characteristics of a given site. Although most [illegible] estation sites are relatively flat, large differen[illegible] site quality may exist as a result of subtle chan[illegible] in topography and geomorphic position. Elevation differences of as little as 10-30 cm (4-12 in) can h[illegible] a major influence on soil drainage, moisture, text[illegible] structure, and pH (Hodges and Switzer [illegible] Stanturf et al. 1998). Afforestation budgets ra[illegible] allow for collection of detailed information on [illegible] or for monitoring water levels for extended peri[illegible] prior to planting. Much can be inferred about [illegible] conditions by examining the soil and any vegeta[illegible] present on the site, but many sites have been h[illegible] altered by flood-control projects, localized drain[illegible] and other modifications, making site assessm[illegible] more difficult.

Several strategies are available to maxim[illegible] successful species-site matches. One such strat[illegible] is to plant a mixture of species that have varied tolerances to flooding or droughty conditions, th[illegible] assuring some level of tree establishment acro[illegible] site. This option is more justified when site conditi[illegible] are not well documented. An alternative strat[illegible] that is more commonly used is to plant species th[illegible] have broad tolerances to a variety of site condition[illegible] It has generally been observed that Nuttall, water [illegible] *nigra*), and willow oaks are the most widely adapt[illegible] species for afforestation projects in the LMAV

Schoenholtz et al. (2001) reported that these 3 species were most frequently selected for afforestation in the Arkansas, Louisiana, and Mississippi portions of the LMAV.

Although broadly recognized, the role that genotypic variation within a given species plays in bottomland hardwood afforestation is not understood. General guidelines are usually conservative, suggesting, for instance, that local seed sources be used where possible. In practice, seed and seedlings often are moved much farther from their original sources, and consequences of these actions for afforestation success, as well as their impacts on genetic diversity, remain unknown.

AFFORESTATION SUCCESSES AND FAILURES

Most bottomland hardwood afforestation projects in the LMAV involve establishment of one to three overstory tree species, most frequently oaks, by either direct-seeding or planting of one-year-old bareroot seedlings (Allen and Kennedy 1989, Strader et al. 1994, Stanturf et al. 1998, Schoenholtz et al. 2001). From strictly an afforestation perspective, as opposed to one of ecological restoration (*sensu* Sharitz 1992, Allen 1997), current approaches have proven generally successful when properly applied. For example, Savage et al. (1989) reported on the results of the first 3 years of operational plantings carried out by the Louisiana Department of Wildlife and Fisheries on the Ouachita Wildlife Management Area, during which 1,355 ha (3,350 ac) were planted. They reported an overall survival rate of 64% for planted seedlings, which was sufficient to reach their goal of an average of 370 seedlings/ha (150 seedlings/ac). Germination rates on their direct-seeded sites also were sufficient to meet their goal for seedling establishment. Similar examples of successful establishment of target species under operational (as opposed to research) conditions have been reported by Allen (1990), Haynes et al. (1995), King and Keeland (1999), and James (2001).

Good documentation of afforestation failures is harder to obtain, but failures clearly are not unusual. Based on a survey of practitioners in the main agencies involved in afforestation in the LMAV, King and Keeland (1999) estimated that 14% (9,147 ha or 22,600 ac) of the land afforested between 1987 and 1997 had to be replanted because of poor plant establishment. Results of the survey reported by Schoenholtz et al. (2001) indicated that only 2,600 ha (6,425 ac), representing 4% of the planted area, were replanted in Arkansas, Louisiana, and Mississippi between 1968 and 1998. Despite this discrepancy in replanting statistics, there is clearly concern regarding the uncertainty of afforestation success under the Conservation Reserve Program and the WRP, which account for the largest amount of land in the LMAV on which afforestation has been attempted. In a survey of the 3,802 ha (9,394 ac) enrolled in the WRP program in 1992, Schweitzer (unpublished data) found that only 9.3% of the area planted had an average stocking of ≥ 250 seedlings/ha (100 seedlings/ac) after 31 months. James (2001) sampled 83 fields within WRP, national wildlife refuges, and state wildlife management areas in Arkansas, Louisiana, and Mississippi that were planted either 3, 5, or 7 years prior to monitoring and observed an average of 662, 1,670, and 1,966 trees/ha (268, 676, 796 trees/ac), respectively. These counts included naturally seeded trees that had established from adjacent seed sources as well as planted trees or acorns.

The proportion of afforestation failures that can be attributed to poor forestry practices is unknown, but likely to be high. Guidance specific to afforestation practices in the LMAV is available (Allen and Kennedy 1989, Kennedy 1993, Stanturf et al. 1998, Allen et al. 2001), and general guidelines on afforestation practices have been available for decades (e.g., Toumey and Korstian 1942). Evidence from the literature (Clewell and Lea 1990, Schweitzer et al. 1997, King and Keeland 1999) and our own personal experience, however, suggests that factors such as use of poor quality planting stock and use of species poorly suited for the site are frequently the causes of afforestation failures.

Although poor planting practices probably account for many, if not most, failures, there are cases where proper forestry practices apparently have been applied and the result has nevertheless been a failure or only partial success. It seems likely that the state of our understanding is not adequate to ensure survival and good growth on all of the types of sites being afforested and for all the species we may want to reestablish. In the following subsections, we highlight what we believe are the major factors contributing to success or failure of afforestation projects in the LMAV.

Herbivory

Herbivores often inflict heavy damage on seed and planted seedlings, which can contribute to high rates of mortality. One of the most significant herbivore problems affecting afforestation projects anywhere in the U.S. occurs in the southern LMAV, where nutria (*Myocastor coypus*) may destroy baldcypress plantings within a few days to a week (Conner 1988, Allen and Boykin 1991, Conner and Buford 1998). Beaver (*Castor canadensis*) are capable of similar levels of damage in some locations (Clewell and Lea 1990, Keeland et al. 1996). In most of the LMAV, however, herbivory problems are caused primarily by mice, rats, raccoon (*Procyon lotor*), rabbits (*Sylvilagus* spp.) and white-tailed deer (*Odocoileus virginianus*). The most common small mammal species associated with herbivory include hispid cotton rats (*Sigmodon hispidus*), deer mice (*Peromyscus maniculatus*), white-footed mice (*P. leucopus*), marsh rice rats (*Oryzomys plaustris*), and house mice (*Mus musculus*).

Data on effects of herbivory and of herbivore populations on afforestation sites have accumulated rapidly in recent years. Savage et al. (1996) reported mortality rates ranging 2-42% attributable to herbivory on afforestation sites in the Ouachita Wildlife Management Area in Louisiana. Wood (1998) documented acorn pilfering as high as 22% and 10% for Nuttall and willow oaks, respectively within the first year of direct seeding on a farmed wetland in the LMAV in Mississippi (Table 5). Burkett and Williams (1998) reported that 97% of 720 container-grown Nuttall oak seedlings were clipped by rodents on an afforestation site located in the Yazoo National Wildlife Refuge in Sharkey County, Mississippi during the first growing season. In October, 1995, Forest Service personnel set 300 small mammal traps over a 3-night period in a portion of the same field used by Burkett and Williams, though at a slightly higher elevation. They caught no fewer than 202 individuals (from a total of 5 species) each night, and the low recapture rate indicated an "extremely dense" population of small mammals (Burkett 1996).

Recent research has demonstrated that important interactions may occur between herbivory and afforestation practices such as seedling or seed selection and timing of planting. Pilfering of direct-seeded acorns has been found to vary by species, sowing depth, and sowing date (Wood 1998). Burkett and Williams (1998) reported a greater degree of herbivore damage to container seedlings than bareroot seedlings at their study site in the Yazoo National Wildlife Refuge in Mississippi, which may be due to the smaller stems and higher nutrient content of the container seedlings (Burkett 1996). Burkett and Williams (1998) also reported that herbivore damage occurred first at their higher elevation plots; they suggested that this may have been due to the greater amount of herbaceous plant cover to protect the rodents, which in turn was related to frequency and duration of flooding.

Some factors responsible for severe herbivore problems can be controlled, though often at a high cost. Reducing herbaceous plant cover during the first growing season may be the single most cost-effective strategy, particularly on large fields. On fields smaller than about 0.8 ha (2 ac) surrounded by forest or fallow agricultural lands, herbivore control may be much more difficult or impractical (Johnson and Krinard 1985*b*). Planting large bareroot seedlings may result in better success than use of direct seeding or container stock when small herbivores or raccoons (in the case of direct seeding) are likely to pose problems. Some repellants provide short-term protection from deer and possibly other herbivores (Graveline et al. 1998). Individual seed or seedlings can be protected by plastic tree shelters or wire mesh cages (Allen and Boykin 1991, Graveline et al. 1998), although the cost is likely to be prohibitive for large-scale afforestation projects.

Competition

Competition from herbaceous vegetation, woody vines, and undesirable tree species can reduce survival and, especially, early growth in plantations of oaks, cottonwoods and other bottomland hardwoods (Miller 1993, Ezell 1995). Guidelines for establishment of commercial plantations therefore have consistently called for intensive pre- and post-planting weed control (McKnight 1970, Malac and Heeren 1979, Miller 1993).

Weed control, particularly after planting, is seldom carried out on sites reforested primarily for wildlife habitat or ecological restoration in the LMAV. Current recommendations, in fact, call for only minimal, site-specific use of weed control, because it may reduce short-term benefits of the site for wildlife, limit establishment of other tree species, and affect other ecological functions (Allen and Kennedy 1989, Strader et al. 1994, Allen et al. 2001). In a summary of factors affecting afforestation success in the LMAV, King and Keeland (1999) did not even list competition from weeds, indicating that it is not perceived as one of the most serious problems faced by restoration practitioners in the region.

The largest effect of weed competition on afforestation success in the LMAV may be indirect, through s influence on herbivore populations. Failures of irect seeding under forest canopies and in small penings adjacent to forest vegetation have been ttributed more to cover provided for rodents than) effects of plant competition (Johnson and Krinard 985*b*). Burkett (1996) suggested that an important eason why there was no detectable herbivory n container grown Nuttall oak seedlings at 1 of er 3 sites was that it had relatively little herbaeous vegetation that could provide cover for small ıammals. Conversely, on sites that had herbaceous over, damage to container seedlings was as high as 8% (Burkett 1996). Good site preparation, which is enerally recommended to include disking or doubleisking to a depth 20-40 cm, appears to be help ontrol both weeds and herbivory in the first growing eason.

Another indirect problem associated with heavy eed cover is its effect on perceptions of success. Beause many bottomland hardwood species, especially aks, have slow initial growth (Hodges and Gardiner 993), a heavy weed cover may give the appearance of planting failure when in fact stocking is acceptable Stanturf et al. 1998).

looding, Drought, and Moisture Relations

Most of the land becoming available for afforestation in the LMAV is considered economically ıarginal for agriculture, and the same traits that ıake these sites poorly-suited for agriculture may lso pose difficulties for afforestation. Timing and uration of flooding, in particular, is the trait that as made much of the available land marginal for griculture, but growing-season droughts are also f critical importance (Johnson and Krinard 1985*a*, tanturf et al. 1998, King and Keeland 1999).

Effects of flooding on survival, growth, and eedling physiology have been described for many ottomland hardwood species (McKevlin et al. 1998, ozlowski 2002). Tolerance of most major species) differing types of flood regimes is relatively well nown (McKnight et al. 1981, Hook 1984, Stanturf ; al. 1998, Kozlowski 2002), and much can be done) mitigate effects of flooding by careful species election. Flooding, however, varies substantially om year-to-year, and the best-planned afforestation rojects may still be adversely affected by flooding.

Seedlings of even the most flood-tolerant species ventually die if completely overtopped for more than few weeks during the growing season (Broadfoot ıd Williston 1973, Baker 1977), an occurrence not ncommon on some afforestation sites. Other types of flooding events that may be rare on a given site, such as extended shallow inundation during the growing season with warm, stagnant water, also will kill large numbers of seedlings. Growing-season flooding stress, if non-lethal, may nevertheless weaken seedlings and increase their susceptibility to subsequent stress, such as drought, later in the same growing season.

Flooding also has important effects on the logistics of afforestation, which in turn may affect cost and likelihood of success in a given year. Flooding can disrupt timing of planting, force extended cold storage of seedlings, and result in planting under more difficult site conditions (Williams and Craft 1998). When flooding is prolonged into early summer, not only is the planting period narrowed substantially, but the period of good growing conditions before the onset of high temperatures and dry soil conditions also is shortened.

Effects of drought may be just as critical as flooding in the LMAV. In fact, drought was listed by more respondents than flooding or herbivory as a major post-planting factor affecting afforestation success in a survey of restoration practitioners (King and Keeland 1999). A severe drought during the 1988 growing season apparently caused failure of direct seeding and planted seedlings on 140 ha (345 ac) (69%) of the land reforested that year on a state wildlife management area in northern Louisiana (Savage et al. 1989). Under controlled conditions, germination of acorns of three species is virtually arrested under simulated soil water potential levels of −0.6 and −1.0 MPa (Smiles and Dawson 1995). Correlations between high seedling mortality and low soil water potential (<-1.0 MPa) were observed during the first growing season after planting at the Lake George Wildlife Restoration Area in Mississippi (Miwa 1993). Effects of drought also are exasperated by high levels of competition from grasses and forbs that rapidly reoccupy afforestation sites. However, the cost of weed control has precluded its common use to date for promoting afforestation in the LMAV.

MONITORING OF FOREST REESTABLISHMENT EFFORTS

There is a growing need to assess the status of afforestation efforts, as area of and interest in afforestation continues to expand throughout the LMAV. This impetus is in part due to a developing awareness of the benefits of forested wetlands, as well as a continuing commitment of support from government programs. As reestablishment efforts continue, there is a growing question about rates of success or failure.

Monitoring of afforestation can range from simplistic to complex, depending on restoration objectives. A prevailing impediment to sound monitoring is that project goals are often not clearly defined. Monitoring thus becomes a poorly defined endeavor. Consequently, conclusions from monitoring are often based on intuition or impressions rather than on quantitative data. Clear objectives are required for monitoring to enable measurement of success or failure.

What to Monitor

Monitoring methods must be designed so that data can be collected consistently, often on sites that have poor access and over time periods that will ultimately range from forest establishment through stages of stand development and maintenance. Attempts to develop practical approaches with proven methods have not been given much attention in afforestation programs within the LMAV. Although more attention is being given to address the need for specific criteria for evaluating what is being done, constraints of time and resources have stymied most efforts. Monitoring approaches must be efficient, economical, and simple in order to help achieve rapid, useful evaluations (Aronson and LeFloc'h 1996). Although simple measures of both structure and function are needed, only the former exists. Species composition and plant cover are readily assessed. However, accurate, simple, efficient, and inexpensive measures of functions, such as nutrient cycling or primary productivity, have yet to be produced. Selection of indicators is dependent on features of the monitored area and priorities of the restoration project. Quantitative indicators, applicable over a full range of efforts, should reveal something about how the ecosystem is responding to management over time. So, we then must identify and quantify ecosystem properties that change in the course of restoration. Most indices are likely to be structural and biotic, although functional attributes and their complexities must also be considered.

Hobbs and Nortone (1996) proposed 6 attributes to be considered in assessing restoration success: (1) composition – species present and their relative abundance, (2) structure – vertical arrangement of vegetation and soil components, (3) pattern – horizontal arrangement of system components, (4) heterogeneity, (5) function, and (6) dynamics and resilience. Objectives, as well as time and resource constraints, will ultimately dictate which attributes can be monitored, how they are observed, and over what time period.

Timing of Monitoring

Timing of monitoring is critical. If monitoring is implemented too soon after planting, inaccurate results may be obtained. However, if sites are not evaluated in a timely manner, then implementing procedures to correct deficiencies may be more costly. Monitoring implies assessing at intervals over time, not just at one point in time. Reflecting on the project goals will aid in the decision on how often to visit a site.

Much debate exists over when to begin monitoring. Ideally, every aspect of the reestablishment procedure should be monitored in order to assess quality control. Timing of monitoring implementation to determine afforestation success may be pre-set if afforestation occurs under federal or state cost-share afforestation or restoration programs. For example, reestablishment under the WRP must be formally evaluated after the third growing season following planting (NRCS 1995).

Most literature on bottomland hardwood afforestation centers on reporting research results, rather than on designing long-term monitoring schemes for evaluation of operational planting. A number of successful oak plantations established by direct seeding and planting seedlings has been reported. In an early study of direct seeding and planting oaks, Johnson (1981) reported that only 2 percent of 8,500 acorns that germinated died during the first year after planting. More than three-fourths of the 1-0 bareroot seedling-stock oaks in this same study were still alive after 10 years. Other published studies that evaluated reestablished stands reported conducting evaluation of establishment success within a range of 1 to 9 years (Krinard and Kennedy 1987, Wittwer 1991, Allen 1990, Schweitzer et al. 1997, Zimmermann 2001).

Researchers at the USFS Center for Bottomland Hardwood Research in Stoneville, Mississippi have a good data base for long-term evaluation of reestablishment success for bottomland hardwoods, particularly oaks (Krinard and Francis 1983, Johnson and Krinard 1987, Kennedy et al. 1987, Krinard and Johnson 1988). Summarizing results of research on direct seeding of oak acorns at this laboratory from the 1960's to 1985, Johnson and Krinard (1985c) concluded a 35% germination expectation, and a 25% chance of producing a free-to-grow tree in 10 years on old fields in the LMAV. Kennedy (1993) suggested that careful monitoring was critical on planted sites in the first 2 years. Results from these studies reinforce the need to match the timing of monitoring with the objectives. If survival of artificially established trees is the primary objective, then sampling following each of the first 3 to 5 growing seasons is likely to provide an adequate estimate of reestablishment status. If objectives extend beyond assessment of early survival, then more site visits and monitoring may be necessary.

Monitoring Methods

Sampling consists of observing a selected portion of a population so that an estimate about the whole population can be made. Considerations are (1) how best to obtain the sample and make the observations and, once the sample data are in hand, (2) how best to use them to estimate the characteristic of the whole population. Obtaining observations involves questions of sample size, how to select the sample, what observational methods to use, and what measurements to record. With most well known sampling designs, the goal is to maximize accuracy and precision within constraints of efficiency and cost (Thompson 1992).

The sampling scheme is one of the most important components of monitoring afforestation success. Identifying how to sample is difficult, and objective driven. In some situations, the measurement parameter of interest may vary continuously over a region. Even a task that appears as simple as counting the number of hardwood stems may prove to be difficult, depending on the distribution of those stems in the population area. The first question often asked is what sample size should be used? Sample size formulae can be used. However, these formulae require an estimate of the population variance, which is frequently unknown prior to sampling. In this case, prior sampling experience under similar conditions in other afforestation fields with similar populations can provide an estimate of expected variance.

Populations of plants tend to exhibit characteristic spatial patterns. Observed patterns, especially in cases where artificial afforestation has been used (i.e., row pattern), are not consistent with a random distribution. The appropriate model for addressing such regularities in spacing is a stochastic point reference (Schweder 1977, Thompson and Ramsey 1987). The stochastic point process gives rise through some probabilistic mechanism to a pattern of point objects in space. Sampling plant and animal populations includes methods with plots, in which every animal or plant within a sample plot is observed, and methods such as line transects or aerial surveys (Cox and Isham 1980, Matern 1986). Detectability is perfect over the plot or line, but a detectability function must be determined as one moves away from the plot or line.

Thompson and Ramsey (1987) have reported comparisons of the mean square prediction errors obtained with plots of different shapes and with detectability functions associated with different survey methods. The most efficient method spreads detectability over the entire study area. Basically, long, thin rectangular plots are more efficient (lowest error term) than square or round plots. In designing a monitoring survey method, decisions must include choice of the size and shape of plots, and how far to travel from a set point or how long to remain at the site.

Finally, systematic and strip adaptive cluster sampling must be considered. With this method, the objective is to estimate the number of point objects, representing the locations, in a clumped population (Thompson 1991). The initial sample consists of randomly selected strips, with small plots. When a plot in the sample contains 1 or more observations, adjacent plots are added to the sample (Thompson 1991).

Criteria For Success

Criteria for success of afforestation of bottomland hardwood forests ultimately relate to providing a forest ecosystem that meets the goals set forth for restoration. These goals may range from simply establishing a stand of trees to restoring a fully functional forest ecosystem that is comparable to the one that was lost. But as previously discussed; constraints of our knowledge and available resources often dictate that only the physiognomy of reestablished vegetation is assessed. To describe structure, attributes such as composition and biomass are measured. This requires determining the species present, the patterns they exhibit, how those species relate to each other and to their environment, and how variable they are from year to year. To observe function, properties and processes that occur through time must be examined.

Monitoring implies periodic assessment, which suggests the need to (1) establish permanent monitoring plots, (2) identify measurable and relevant traits, and (3) revisit plots and re-collect data over time. Interpreting data and determining success are done in context to project objectives. Comparisons with similar types of projects within local landscapes or use of reference areas have commonly been made to judge degree of success (VanHorn and VanHorn 1996). Others have argued that use of historical records is a suitable guide for evaluating restoration success in dynamic systems (Shear et al. 1996).

Just as there is not a standard prescription for developing afforestation plans, development of monitoring schemes is also subjective and depends on project objectives and available resources. Some degree of monitoring is necessary to (1) ensure that the project objectives are achieved and (2) evaluate possible causes when objectives are not achieved. Monitoring relevant and sensitive environmental indicators, assessing progress relative to project goals, and making adjustments to procedures in order to maximize the likelihood of current and future success are key elements for a successful monitoring program. Quality assessment and control throughout every stage of an afforestation or restoration project is crucial to keep errors to a minimum and to promote success. Restoration programs must be more pro-active by including monitoring systems with quality control assessments so that restoration procedures can be modified if data from on-going evaluations suggest they are needed.

CURRENT CHALLENGES AND OPPORTUNITIES

Those involved with restoration of bottomland hardwood ecosystems in the LMAV are faced with considerable challenges at several levels. Firstly, although there is a growing knowledge base of afforestation practices in the LMAV, project goals are not always met because of inappropriate afforestation decisions. Afforestation techniques for this region are generally well developed (e.g., Allen and Kennedy 1989, Strader et al. 1994, Stanturf et al. 1998, Allen et al. 2001), yet there remain significant shortcomings with operational planting efforts (e.g., Schweitzer, unpublished data, King and Keeland 1999, Schoenholtz et al. 2001). As a specific example, knowledge of site variation due to small changes in topography within floodplains of the LMAV in combination with knowledge of site requirements of species to be used must be incorporated into afforestation decisions in order to maximize successful establishment of trees.

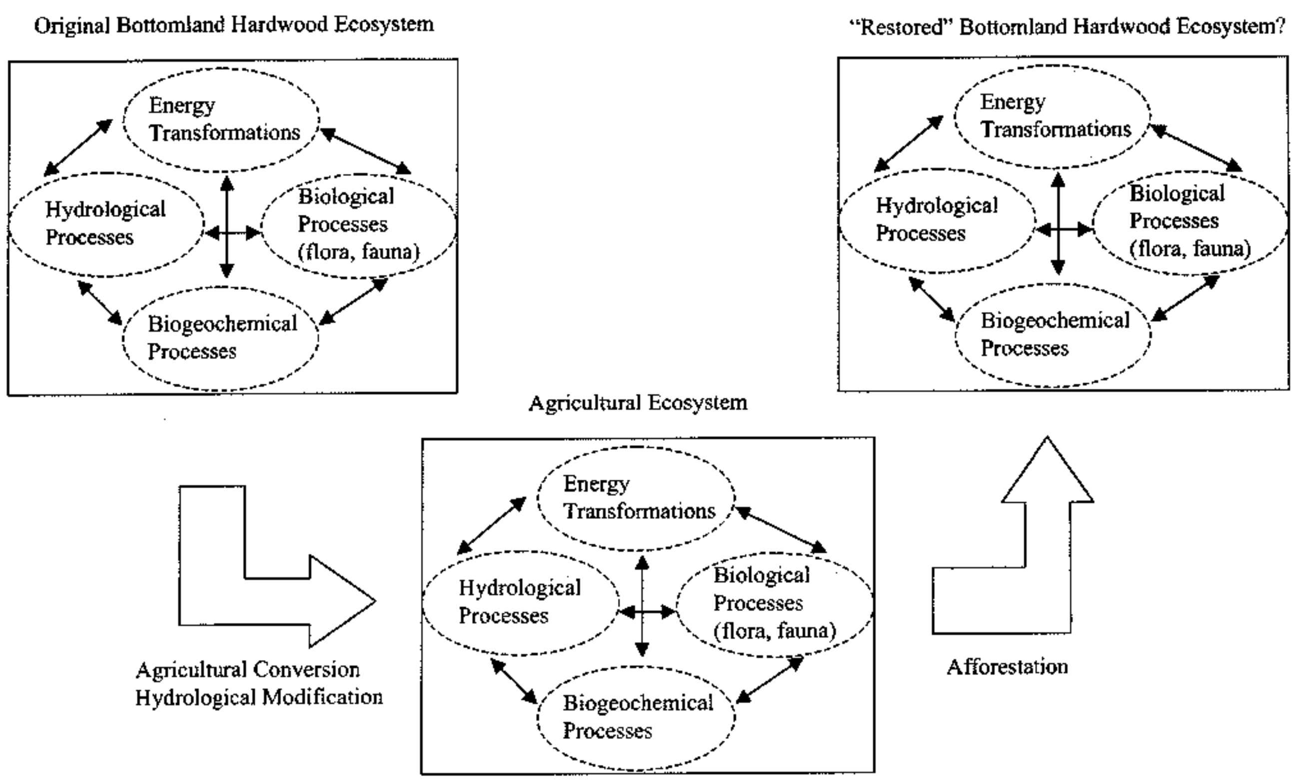

Figure 1. Categories of generalized ecological functions to consider for restoration of bottomland hardwood ecosystems.

A second challenge is presented by the sometimes-ambiguous relationship between bottomland hardwood afforestation and restoration of ecologically functional hardwood bottomland forest ecosystems (Fig. 1). Although afforestation is often an integral component of restoration that can accelerate establishment of forest composition and structure, there are many other ecological functions of bottomland hardwood ecosystems that are not restored readily by reestablishing trees and may require many decades to develop a fully functional capacity. However, this ambiguity can be minimized by clearly specifying the objective of a restoration project so that the degree to which objectives are being met can be appropriately assessed. Monitoring programs are essential for this process, but the notion of "success" or "failure" must be clearly defined for these programs to be useful.

A third challenge is that availability of research information lags far behind implementation of bottomland hardwood afforestation. Considering the longtime frames for newly established forest growth and development, research of afforestation, stand development, and corresponding restoration of ecological functions can take decades before answers to current restoration questions can be provided. In this context, there is a necessity to use adaptive management approaches, whereby management decisions for afforestation are coupled with research results in a feedback framework that provides flexibility to alter management approaches as new information from research and from prior afforestation experiences becomes available.

Interest in restoring the imperiled bottomland hardwood forests of the LMAV is unprecedented and is reflected in the presence of government programs to promote afforestation of marginal agricultural lands. Although approximately 75,000 ha (185,000 ac) have been planted in the LMAV to date, estimates for potential additional afforestation range from approximately 240,000 ha (593,000 ac) (Lower Mississippi Valley Joint Venture) to >3,000,000 ha (>7,413,000 ac) (Amacher et al. 1997). This presents remarkable opportunities to (1) accelerate natural restoration patterns of succession through management that is based on sound ecological theory, (2) create habitat for wildlife, (3) connect existing fragmented bottomland hardwood forests, (4) potentially sequester carbon in the developing forests and thereby provide potential carbon credits for landowners, and (5) restore many of the valuable functions provided by hardwood bottomland ecosystems in the LMAV.

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